CAN MYOCARDIAL PERFORMANCE INDEX BE MEASURED BY M-MODE COLOR TISSUE DOPPLER THROUGH THE AORTIC VALVE (PRELIMINARY RESULTS)

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ABSTRACT

Introduction*: Myocardial performance index (MPI) (the sum of isovolumic contraction [IVCT] and isovolumic relaxation [IVRT] divided by ejection time [ET]) is a useful method of left ventricular function assessment. MPI can be calculated based on measurements of left ventricular intervals by pulsed wave Doppler, pulsed wave tissue Doppler [pw TDI], color tissue Doppler [c TDI], M-mode color TDI through the anterior mitral leaflet, etc.*

Aim*: The aim of our study is to test a possible method of LV intervals measurement and MPI calculation, namely M-mode color TDI through the aortic valve.*

Materials and methods*: Eighty four (84) subjects, including 37 patients with arterial hypertension (AH), 21 patients with coronary artery disease (CAD) and 26 healthy subjects were studied. In all participants IVCT, ET and IVRT were measured using four different echocardiographic methods: 1) pw Doppler, 2) pw TDI, 3) M-mode color TDI through the anterior mitral leaflet, and 4) M-mode color TDI through the aortic valve. MPI based on these four methods of measurement was calculated. MPI by M-mode color TDI through the aortic valve was assessed in two variants (MPI_{AO1}, MPI using the two phases of IVCT, and MPI_{AO2}, MPI using only the second phase of IVCT).*

Results*: MPI_{AO1} and MPI_{AO2} showed good correlation with the three reference methods of measurement used. The highest correlation was found between MPI_{AO2} and MPI by M-mode TDI through the anterior mitral leaflet (r_s=0.848, P<0.001) in coronary artery disease patients.*

Conclusion*: Calculation of MPI based on M-mode TDI through the aortic valve could be a useful method in comprehensive echocardiographic evaluation. It could be used for current assessment of the patients and for their follow-up.*

Keywords: *Myocardial performance index, left ventricular intervals, M-mode, color tissue Doppler, aortic valve.*

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Introduction

The original method of precise left ventricular function evaluation was the assessment by heart catheterization[(1)]. Later many echocardiographic methods were developed[(2-5)]. In 1995, Tei et al. offered an index for assessment of global (systolic and diastolic) heart function based on pulsed Doppler recording of aortic and mitral flow velocity[(6-8)]. The index is known as Tei-index or "Myocardial Performance Index" (MPI). The MPI is calculated as: MPI = (a - b) / b, where "a" is the interval from the end to the onset of the mitral inflow, and "b" is the duration of the systolic aortic blood flow, i.e. the ejection time (ET).

Thus, "a - b" is the sum of the isovolumic contraction time (IVCT) and the isovolumic relaxation time (IVRT): MPI = (IVCT + IVRT) / ET. The normal MPI in healthy adults is 0.39 ± 0.05. According to Tei et al. MPI ≥ 0.50 indicates global left ventricular dysfunction[(8)].

MPI can also be calculated based on the left ventricular (LV) intervals, measured by pulsed wave tissue Doppler imaging (pw TDI)[(9-11)], color TDI[(12)], M-mode color TDI through the anterior mitral leaflet[(13-15)], etc.

The aim of our study is to test a possible method of LV intervals measurement and MPI calculation, namely M-mode color TDI through the aortic valve.

Methods

Study population

Eighty four (84) subjects, including 37 patients with arterial hypertension (AH), 21 patients with coronary artery disease (CAD) and 26 healthy subjects were studied. Coronary artery disease was defined as previous myocardial infarction or CAD proven by coronary angiography. The investigated hypertensive patients were distributed as follows: 19 women and 18 men (51.35% and 48.65% of AH patients, respectively). The mean age of the AH patients was 60.54±14.45 years. The distribution of the patients with coronary artery disease was as follows: 10 women and 11 men (47.62% and 52.38% of CAD patients, respectively). The mean age of the CAD patients was 63.71±10.08 years. The mean age of the 26 healthy controls studied was 52.43±12.02 years, and the gender distribution was 14 women (53.85%) and 12 men (46.15%).

The study was approved by the local ethical committee. All patients signed informed consent for participation in the study.

The patients with conduction blocks, atrial fibrillation, greater than mild valve regurgitation, valve stenosis, and with suboptimal echocardiograms were excluded.

Echocardiography

The participants were examined using an iE33 (Philips Medical systems, Andover, MA, USA) ultrasound equipment, with an S5 transducer. The study was performed with the participants in a left lateral decubitus position. All measurements were performed on 3 to 5 cardiac cycles, while holding breathing in the expiration phase.

In all patients thorough echocardiographic examination was performed including M-mode echocardiography; B-mode examination with left ventricular ejection fraction measurement; color, pulsed wave, and continuous wave Doppler examination; color and pulsed wave tissue Doppler examination. The left ventricular mass was calculated using the Devereux formula[16,17]: LV mass = 0.8 × [1.04 × [(LVEDD + IVS + PW)^3 -LVEDD^3] + 0.6 g. In pw Doppler, pw TDI, and M-mode color TDI recordings 150 mm/sec sweep speed was used.

In all participants IVCT, ET and IVRT were measured using four different echocardiographic methods:

• pulsed wave Doppler with separate recording of aortic and mitral flow,

• pulsed wave TDI,

• M-mode color TDI through the anterior mitral leaflet,

• M-mode color TDI through the aortic valve.

MPI based on these four methods of measurement was calculated.

Pulsed wave Doppler

The examination was performed using the method with separate registration of mitral inflow and aortic outflow[18-20]. For this purpose the Doppler sample volume was positioned at the tips of the mitral valve leaflets and then displaced into the left ventricular outflow tract immediately below the aortic valve.

The following time intervals were measured:

1) the interval from the end to the onset of the mitral inflow ("a"),

2) the duration of the aortic systolic blood flow (ET, "b"),

3) the interval from the R-wave on ECG to the onset of the mitral diastolic flow ("c"),

4) the time from the R-wave to the end of the systolic flow through the aortic valve (aortic valve closure) ("d"). As a reference point for this measurement the click of aortic valve closure was used.

Using these data the following variables were calculated:

• $IVRT_{PW}$ - time from the R-wave to the onset of the mitral diastolic blood flow ("c") minus the time from the R-wave to the end of the aortic systolic flow ("d") ($IVRT_{PW}$ = c - d);

• $IVCT_{PW}$ - time from the end to the onset of mitral inflow ("a") minus the sum of the ejection time (ET, "b") and $IVRT_{PW}$ ($IVCT_{PW}$ = a - (ET_{PW} + $IVRT_{PW}$);

• MPI_{PW} = (a - b) / b.

Pulsed wave TDI

The studies were conducted at the lateral and medial mitral annulus and the results from the two zones were averaged. For this purpose the sample volume of the pulsed wave tissue Doppler was positioned at the lateral and medial mitral valve annulus. The pulsed wave tissue Doppler signal gain was corrected so as to obtain high quality images at the least possible gain. The Nyquist limit was set to 15 cm/s. The tissue Doppler area was reduced to obtain a maximum frame rate. All measurements were performed in 3-5 heart cycles, while holding breathing during expiration.

The following variables were measured:

IVCT - time from the end of late diastolic velocity (A') to the beginning of systolic velocity (S') at the medial ($IVCT_M$) and lateral ($IVCT_L$) mitral annulus;

ET - interval from the onset to the end of S' in both zones (ET_M and ET_L);

IVRT - time from the end of S' to the beginning of E' at the medial ($IVRT_M$) and lateral ($IVRT_L$) mitral annulus. The results from lateral and medial mitral annulus were averaged to obtain $IVCT_{PWTDI,}$ ET_{PWTDI} and $IVRT_{PWTDI}$.

MPI was calculated as MPI = (IVCT + IVRT) / ET.

M-mode color TDI through the anterior mitral leaflet

These examinations were performed using the method proposed by Biering-Sørensen et al.[21-23]. The studies were conducted using apical four chamber view. In these studies the tissue Doppler area was also corrected to obtain a maximum sample rate of the tissue Doppler.

On the M-mode color TDI records the points used for LV intervals measurement were as follows[24,25]:

• mitral valve closure (MVC) - transition of the color from blue/turquoise to red;

• aortic valve opening (AVO) - transition of the color from blue to red;

• aortic valve closure (AVC) - color change from red to blue;

• mitral valve opening (MVO) - color transition from red to orange (Fig. 1a). Using these points IVCT, ET and IVRT were measured (Fig. 1b) and MPI was calculated using the aforementioned formula.

M-mode color TDI through the aortic valve

The measurement of the LV intervals using M-mode color TDI through the aortic valve is the method tested in this work.

Theoretical basis of the method

The theoretical basis for this method is to combine the advantages of two echocardiographic methods, namely M-mode echocardiography and color Doppler TDI. The aim is to use in combination the advantages of the two methods. M-mode echocardiography offers a very good temporal resolution and possibility for direct visualization of the movement of the aortic valve and accurate determination of the moments of its opening and closing. This would allow precise measurement of the ejection time, accurate determination of the end of IVCT and the onset of IVRT. On the other hand, the intention is to use the M-mode color TDI capability to read left ventricular intervals based on the color coding of the tissue velocities. Thus, it allows registration of IVCT onset and the IVRT end. Hence, it allows measurement of IVCT and IVRT. In addition, the change in color coding can be used in determining the moments of the aortic valve opening and closure.

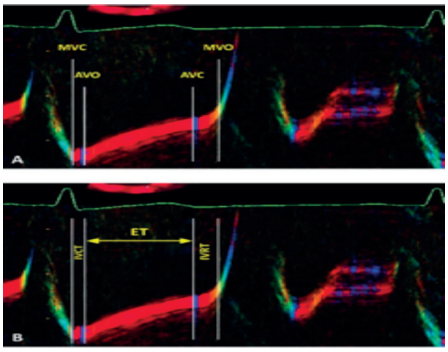

Figure 1: Reference points for LV intervals measurement (**A**) and LV intervals (**B**) according to the method proposed by Biering-Sørensen et al. The point reflecting aortic valve closure was originally reported by Voigt et al.[24] and Aase et al.[26] compared the timing of aortic valve closure visually seen in high frame B-mode images with simultaneously recorded apical tissue Doppler imaging (TDI) and speckle-tracking-based velocity/time curves. *MVC, mitral valve closure, AVO, aortic valve opening, AVC, aortic valve closure, MVO, mitral valve opening*

Technique of the study

The technique of the study was as follows:

• Obtaining a B-mode color TDI image in apical long axis view of the left ventricle;

• Color Doppler TDI area reduction to achieve the highest possible sample rate;

• Enlarging the image for good aortic valve visualization;

• Positioning the line for M-mode study through the aortic valve (Fig. 2);

• Measurement of intervals using the M-Mode color TDI recording obtained through the aortic valve.

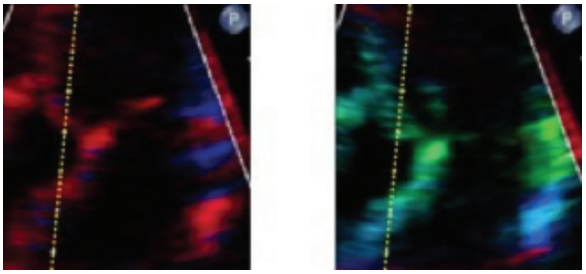

Figure 2: Position of the line for M-mode TDI recording through the aortic valve (images from one and the same patient in different cardiac cycle moments).

IVCT, ET and IVRT were measured as follows:

IVCT - from the color change of the aortic valve M-mode color TDI recording from blue to red in the final phase of the diastole to the onset of the opening of the aortic leaflets, visualized by a small yellow band. During the isovolumic contraction a biphasic motion of the aortic leaflet is recorded (Fig. 3). During the first phase, the displacement is directed to the transducer, and accordingly is coded in red (positive velocity). The second phase represents a backward motion, the speed is negative and is coded in blue or turquoise. At the end of this phase, a small yellow streak is usually visualized, reflecting the moment of onset of the aortic valve opening. The two phases of the aortic valve motion during IVCT correspond to the two phases of IVCT in basal septum color M-mode TDI, denoted by Lind at al. as $IVCt_m pos$ и $IVCt_m neg$[27]. The measurements of IVCT were performed in two variants: $IVCT_{AO1}$ (sum of the two IVCT phases) and $IVCT_{AO2}$ (the second IVCT phase).

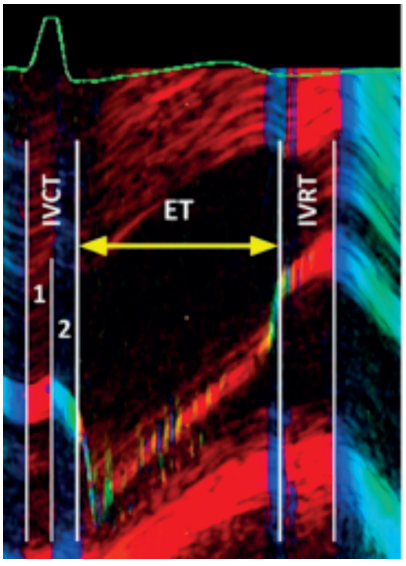

Figure 3: An example of M-mode color TDI through the aortic valve. The two phases of the isovolumic contraction (1 and 2) and the color in which they are depicted can be seen.

ET_{AO} - interval from the beginning of the opening motion to the end of the closure motion, in most cases encoded by a small yellow strips. The method allows to select the better indicator, namely the color coding of the velocity or the image of M-mode motion.

$IVRT_{AO}$ - time from the aortic valve closure to the end of the coded in red isovolumic relaxation. The IVRT end is marked by a transition from red to blue. The motion during isovolumic relaxation is single-phase, with the velocity being positive during all this interval.

As in other methods, 3 to 5 measurements of each interval were averaged.

MPI_{AO} was calculated using the standard formula: $MPI_{AO1} = (IVCT_{AO1} + IVRT_{AO}) / ET_{AO}$ and $MPI_{AO2} = (IVCT_{AO2} + IVRT_{AO}) / ET_{AO}$.

Statistics

For the statistical processing of survey data, a SPSS 21.0 statistical package for Windows was used. The data are presented as mean values ± standard deviation (mean ± SD). The results are presented as absolute values and relative frequencies (percentages). For hypotheses verifying dispersion analysis (ANOVA, analysis of variance) and independent samples t-test were used. The verification for distribution normality was performed by the methods of Kolmogorov-Smirnov and Shapiro-Wilk. The comparison of two groups with non-normal distribution was performed by Mann-Whitney. Pearson correlation coefficient was used for correlation assessment in cases of normal distribution of two quantitative variables. Spearman correlation coefficient was used for assessment of the correlation in cases of non-normal distribution of the quantitative variables. The critical significance level was $\alpha = 0.05$, with the zero hypothesis being rejected at the P-value < α.

Results

Anthropometric data

The weight of the healthy controls (70.73±15.24 kg) was significantly lower than the weight of the AH patients (83.24±14.70 kg) (P<0.01). The weight of the CAD patients (78.29±19.88 kg) did not differ significantly from the weight of the control and AH patients. The control patients body mass index (BMI) (23.56±3.80) was significantly less than BMI of AH patients (28.95±4.23) and CAD patients (27.35±5.10) (P<0.001 and P<0.01, respectively).

Echocardiographic study

Left ventricular mass

In healthy subjects, LV mass was 160.5±38.9

g. In AH patients the mass of the left ventricle was 220.43±44.66 g and in CAD patients it was 233.53±52.54 g. The LV mass in hypertensive patients and coronary artery disease patients was significantly larger than the LV mass in healthy subjects (P<0.001 for both comparisons). The difference between LV mass in AH and CAD patients was not significant (P=NS).

Ejection fraction

In the three groups studied the ejection fraction found was as follows: healthy persons – 64.89±2.7%, AH patients – 62.55±3.35%, CAD patients – 57.5±8.03%. The lowest EF was found in CAD patients. The EF in healthy persons was significantly higher than the EF in AH patients and CAD patients (P<0.01 and P<0.001, respectively). The EF in AH patients and CAD patients also differed significantly (P<0.01).

Left ventricular intervals

The values of LV intervals in the three groups obtained using the different methods are shown in Table 1.

IVCT. $IVCT_{PW}$, $IVCT_{AO1}$ and $IVCT_{AO2}$ in the three groups showed no significant difference (P=NS). $IVCT_{PWTDI}$ and $IVCT_{MV}$ were significantly longer in hypertensive and CAD patient compared to the healthy subjects (P<0.05). There was no significant difference between AH and CAD patients (P=NS).

ET. ET_{PW} in control subjects and AH patients did not differ significantly (P=NS), and in CAD patients ET_{PW} was significantly longer than in AH patients (P<0.05). In control patients, ET_{PWTDI} and ET_{MV} were significantly longer compared to AH patients (P<0.05). The difference of ET_{PWTDI} and ET_{MV} between CAD and AH patients, and controls and CAD patients was not significant (P=NS). ET_{AO} did not differ significantly between control subjects and AH patients (P=NS). In CAD patients ET_{AO} was significantly longer compared to controls and AH patients (P<0.05).

IVRT. $IVRT_{PW}$ in AH and CAD patients was significantly longer compared to control subjects (P<0.001), but did not differ significantly between AH patients and CAD patients (P=NS). $IVRT_{PWTDI}$ in control subjects was significantly shorter compared to AH and CAD patients (P<0.001). The difference between AH and CAD patients was also significant (P<0.01). $IVRT_{MV}$ and $IVRT_{AO}$ in hypertensive patients and CAD patients was significantly longer in comparison with healthy subjects (P<0.001), but the difference between AH and CAD patients was not significant (P=NS).

Myocardial performance index

MPI calculated by pulsed wave Doppler (MPI_{PW}), pulsed wave TDI (MPI_{PWTDI}), M-mode color TDI through the anterior mitral leaflet (MPI_{MV}) and M-mode color TDI through the aortic valve (MPI_{AO}) was significantly higher in hypertensive and CAD patients compared to healthy subjects (Fig. 4) with P value < 0.001 in most comparisons except MPI_{PW} in controls to CAD patients where P value was < 0.05, and MPI_{AO1} and MPI_{AO2} in controls to CAD patients where P value was < 0.01. The difference in MPI between hypertensive and CAD patients was not significant (P=NS).

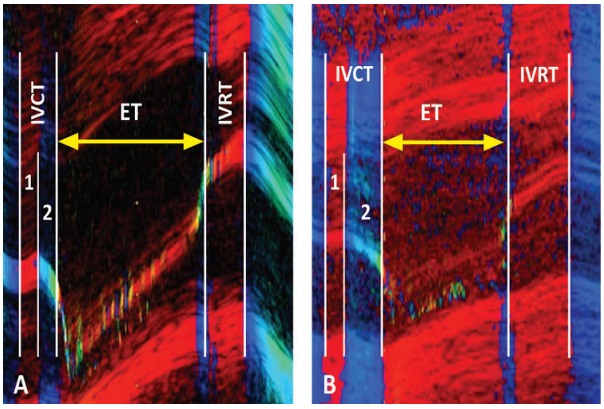

Figure 4:. M-mode color TDI through the aortic valve in a healthy person (**A**) and in a patient with a previous myocardial infarction and left ventricular dysfunction (**B**). In the patient with myocardial infarction IVCT and IVRT are longer and ET is shorter. Accordingly in the second subject the value of MPI ([IVCT+IVRT]/ET) is greater.

Correlation of MPI_{AO} with MPI calculated using other methods

Healthy subjects

MPI_{AO1}. In control subjects, the correlation found between MPI_{AO1} and MPI_{PW}, $MPI_{PWTDI,}$ and MPI_{MV} was as follows: MPI_{AO1} to MPI_{PW} - r=0.695, P<0.001; MPI_{AO1} to MPI_{PWTDI} - r=0.746, P<0.001; MPI_{AO1} to MPI_{MV} - r=0.598, P=0.001.

MPI_{AO2}. The correlation between MPI_{AO2} and MPI_{PW}, MPI_{PWTDI}, and MPI_{MV} was following: MPI_{AO2} to MPI_{PW} - r=0.519, P<0.05; MPI_{AO2} to MPI_{PWTDI} - r=0.611, P=0.001; MPI_{AO2} to MPI_{MV} – r=0.644, P<0.001.

Variable	Controls (n=26)		AH (n=37)		CAD (n=21)		P	P	P
	Mean	±SD	Mean	±SD	Mean	±SD	*	†	‡
$IVCT_{PW}$ (ms)	48.46	16.30	45.77	14.55	42.85	14.73	NS	NS	NS
$IVCT_{PWTDI}$ (ms)	65.18	12.99	72.87	14.58	78.16	15.96	< 0.05	< 0.01 ¥	NS ¥
$IVCT_{MV}$ (ms)	33.08	5.99	37.58	9.44	38.29	9.67	< 0.05	< 0.05	NS
$IVCT_{AO1}$ (ms)	71.73	16.95	73.59	15.57	73.91	18.88	NS ¥	NS ¥	NS ¥
$IVCT_{AO2}$ (ms)	37.70	9.36	40.83	9.21	38.26	10.59	NS	NS ¥	NS ¥
ET_{PW} (ms)	288.36	18.98	285.78	20.66	303.12	32.49	NS	NS	< 0,05
ET_{PWTDI} (ms)	288.61	19.89	276.86	20.84	288.17	31.54	< 0.05	NS	NS
ET_{MV} (ms)	277.18	19.20	264.94	21.31	279.58	34.09	< 0.05	NS	NS
ET_{AO} (ms)	289.22	20.46	287.63	21.65	305.00	32.68	NS ¥	<0.05	< 0,05 ¥
$IVRT_{PW}$ (ms)	66.77	10.09	96.72	17.73	102.58	26.56	<0.001	<0.001	NS
$IVRT_{PWTDI}$ (ms)	63.59	8.93	84.87	21.75	99.96	17.51	<0.001	<0.001	<0.01
$IVRT_{MV}$ (ms)	81.44	14.31	109.96	20.42	120.18	26.83	<0.001	<0.001 ¥	NS ¥
$IVRT_{AO}$ (ms)	70.59	11.89	95.79	15.53	105.42	22.18	<0.001	<0.001 ¥	NS ¥
MPI_{PW}	0.40	0.07	0.50	0.09	0.49	0.14	<0.001 ¥	< 0.05	NS ¥
MPI_{PWTDI}	0.45	0.06	0.57	0.12	0.63	0.12	<0.001	<0.001	NS
MPI_{MV}	0.42	0.07	0.56	0.11	0.58	0.18	<0.001	<0.001 ¥	NS ¥
MPI_{AO1}	0.49	0.08	0.59	0.09	0.60	0.15	<0.001	<0.01 ¥	NS ¥
MPI_{AO2}	0.38	0.06	0.48	0.08	0.48	0.14	<0.001	<0.01 ¥	NS ¥

Table 1: Left ventricular intervals and myocardial performance index in control subjects, hypertensive patients, and coronary artery disease patients.

**, significance of the difference between healthy subjects and AH patients, †, significance of the difference between healthy subjects and CAD patients, ‡, significance of the difference between AH and CAD patients*

¥, The significance of the difference in these comparisons is assessed using Mann-Whitney U-test because of the non-normal distribution of the respective variables in hypertensive patients group and/or coronary artery disease group.

Patients with arterial hypertension

In AH patients, MPI_{PW} values showed mild non-normal distribution. These values were converted to normal distribution and after that the correlation analysis was performed using Pearson's r.

MPI_{AO1}. In AH patients, the correlation established between MPI_{AO1} and $MPI_{PW,}$ $MPI_{PWTDI,}$ and MPI_{MV} was as follows: MPI_{AO1} to MPI_{PW} - r=0.796, P<0.001; MPI_{AO1} to MPI_{PWTDI} - r=0.618, P<0.001; MPI_{AO1} to MPI_{MV} – r=0.757, P<0.001.

$MPI_{AO2.}$ The correlation between MPI_{AO2} and MPI_{PW}, MPI_{PWTDI}, and MPI_{MV} was following: MPI_{AO2} to MPI_{PW} - r=0.767, P<0.001; MPI_{AO2} to MPI_{PWTDI} - r=0.702, P<0.001; MPI_{AO2} to MPI_{MV} – r=0.784, P<0.001.

Patients with coronary artery disease

Because of the non-normal distribution of MPI_{AO1} and MPI_{AO2} values in this group of patients, the correlation was assessed using Spearman's rho.

MPI_{AO1}. In CAD patients, the correlation found between MPI_{AO1} and MPI_{PW}, MPI_{PWTDI}, and MPI_{MV} was as follows: MPI_{AO1} to MPI_{PW} - rs=0.709, P<0.001; MPI_{AO1} to MPI_{PWTDI} - rs=0.648, P=0.001; MPI_{AO1} to MPI_{MV} - rs=0.790, P<0.001.

$MPI_{AO2.}$ The correlation between MPI_{AO2} and MPI_{PW}, MPI_{PWTDI}, and MPI_{MV} was following: MPI_{AO2} to MPI_{PW} - rs=0.765, P<0.001; MPI_{AO2} to MPI_{PWTDI} - rs=0.614, P<0.01; MPI_{AO2} to MPI_{MV} - rs=0.848, P<0.001.

Discussion

MPI by pw Doppler and MPI by pw TDI

Difference

In most studies, the results for MPI_{PWTDI} in healthy subjects showed higher values compared to MPI_{PW}[19,28,29]. According to Gaibazzi et al.[28] it is appropriate to use higher values of MPI_{PWTDI} compared to MPI_{PW} to distinguish normal from pathological results. Our results correspond to these data. In healthy persons, MPI_{PW} was 0.402±0.074 and MPI_{PWTDI} was 0.447±0.064. The values of MPI_{PW} and MPI_{PWTDI} differed significantly (P<0.05). A similar difference was observed in the patients with arterial hypertension (MPI_{PW} - 0.501±0.088 and MPI_{PWTDI} - 0.573±0.120, P<0.01) and in the coronary artery disease patients (MPI_{PW} - 0.492±0.142 and MPI_{PWTDI} - 0.626±0.118, P<0.01).

Correlations

The data concerning the correlation between pw spectral Doppler and pw TDI in MPI calculation are contradictory.

Tekten et al.[30] found a high correlation between MPI measured by the two methods. The highest correlation was observed between MPI_{PW} and mean values of MPI by TDE: r = 0.94, P<0.0001 in healthy subjects; and r = 0.95, P<0.0001 in patients with dilated cardiomyopathy. In patients with prior myocardial infarction Rojo et al.[9] found significant but only mild to moderate degree of agreement between TDI MPI measured at septal mitral annulus (tMPIs) and conventional MPI (95% confidence interval [CI] ICC = 0.36-0.69). According to the authors tMPI should be defined as a different index, and not as an alternative way to obtain classic MPI[9]. Duzenli et al.[19] also found moderate correlation between MPI by the two methods (ICC = 0.53 in the healthy subjects and ICC = 0.57 in the patients with heart failure). Alsafi et al. (10) studied MPI in 32 female athletes and 34 sedentary controls using MPI measured with pw Doppler and TDI. The agreement and correlation between conventional LV MPI by pw Doppler compared to MPI by TDI were very poor in both populations (r = 0.12 in the athletes group and r = 0.30 in the sedentary controls)[10].

Our data concerning the correlation between MPI by these two methods showed moderate correlation between MPI_{PW} and MPI_{PWTDI} in the control group (r = 0.508, P<0.01) and in patients with arterial hypertension (r = 0.552, P<0.001).

In CAD patients, the correlation between MPI_{PW} and MPI_{PWTDI} was higher (r = 0.722, P<0.001).

M-mode color TDI through the anterior mitral leaflet

Difference

In healthy subjects, MPI_{MV} (0.415±0.067) did not differ significantly from MPI_{PW} (0.402±0.074) (P=NS) and MPI_{PWTDI} (0.447±0.064, P=NS). In AH patients, MPI_{MV} (0.560±0.112) was significantly higher than MPI_{PW} (0.501±0.088, P<0.05), but not differed significantly from MPI_{PWTDI} (0.573±120, P=NS). In CAD patients, MPI_{MV} (0.584±0.179) was significantly higher than MPI_{PW} (0.492±0.142, P<0.05) and also did not differ significantly from MPI_{PWTDI} (0.626±0.118, P=NS).

Correlations

In healthy subjects, we found a significant but weak correlation between MPI_{MV} and MPI_{PW} (r = 0.394, P<0.05), and the correlation between MPI_{MV} and MPI_{PWTDI} was not significant (r = 0.364, P=0.067). In AH patients, we found a higher correlation between MPI_{MV} and MPI_{PW} (r = 0.673, P<0.001) and between MPI_{MV} and MPI_{PWTDI} (r = 0.656, P<0.001). Because of the non-normal distribution of the MPI_{MV} values in the CAD patients, in this group of patients the correlation was assessed using Spearman's rho. In these patients, the correlation between MPI_{MV} and MPI_{PW} (rs = 0.819, P<0.001) was very strong, and the correlation between MPI_{MV} and MPI_{PWTDI} (rs = 0.622, P<0.01) was strong.

M-mode color TDI through the aortic valve

MPI_{AO1}

Difference

In control subjects, MPI_{AO1} (0.496±0.075) was significantly higher than MPI_{PW} (0.402±0.074, P<0.001), MPI_{PWTDI} (0.447±0.064, P<0.05), MPI_{AO2} (0.376±0.058, P<0.001), and MPI_{MV} (0.415±0.067, P<0.001). In AH patients, MPI_{AO1} (0.591±0.089) was also significantly higher than MPI_{PW} (0.501±0.088, P<0.001) and MPI_{AO2} (0.477±0.077, P<0.001), but did not differ significantly from MPI_{PWTDI} (0.573±120, P=NS) and MPI_{MV} (0.560±0.112, P=NS). In CAD patients, MPI_{AO1} (0.600±0.150) was significantly higher than MPI_{PW} (0.492±0.142, P<0.05), and MPI_{AO2} (0.482±0.135, P<0.01), but there were no significant difference

from MPI_{PWTDI} (0.626±118, P=NS) and MPI_{MV} (0.584±0.179, P=NS).

Correlations

In all groups studied, a high correlation between MPI_{AO1}, on the one hand, and $MPI_{PW,}$ MPI_{PWTDI}, and $MPI_{MV,}$ on the other hand, was found. In healthy patients, the highest correlation was observed between MPI_{AO1} and MPI_{PWTDI} (r=0.746, P<0.001), followed by MPI_{AO1} to MPI_{PW} (r=0.695, P<0.001), and MPI_{AO1} to MPI_{MV} (r=0.598, P=0.001). In AH patients the highest correlation was found between MPI_{AO1} and MPI_{PW} (r=0.796, P<0.001), followed by MPI_{AO1} to MPI_{MV} (r=0.757, P<0.001), and MPI_{AO1} to MPI_{PWTDI} (r=0.618, P<0,001). In CAD patients the strongest correlation was observed between MPI_{AO1} and MPI_{MV} (rs=0.790, P<0.001), followed by MPI_{AO1} to MPI_{PW} (rs=0.709, P<0.001), and MPI_{AO1} to MPI_{PWTDI} (rs=0.648, P=0.001).

MPI_{AO2}

Difference

In control subjects, MPI_{AO2} (0.376±0.058) did not differ significantly from MPI_{PW} (0.402±0.074, P=NS), but it was significantly lower than MPI_{PWTDI} (0.447±0.064, P<0.001) and MPI_{MV} (0.415±0.067, P<0.05). In AH patients, MPI_{AO2} (0.477±0.077) also did not differ significantly from MPI_{PW} (0.501±0.088, P=NS) and it was significantly lower than MPI_{PWTDI} (0.573±0.120, P<0.001) and MPI_{MV} (0.560±0.112, P<0.001). As in previous two groups, in CAD patients, MPI_{AO2} (0.482±0.135) did not differ significantly from MPI_{PW} (0.492±0.142, P=NS), but it was significantly lower than MPI_{MV} (0.584±0.179, P<0.05) and MPI_{PWTDI} (0.626±118, P=0.001 P<0.001).

Correlations

In healthy patients, best correlation was found between MPI_{AO2} and MPI_{MV} (r=0.644, P<0.001). The correlations between MPI_{AO2} and MPI_{PWTDI} (r=0.611, P=0.001) and between MPI_{AO2} and MPI_{PW} (r=0.519, P<0.05) were lower. In AH patients, we found higher correlations between MPI_{AO2} and $MPI_{PW,}$ MPI_{PWTDI}, and MPI_{MV}: MPI_{AO2} to MPI_{MV} (r=0.784, P<0.001), followed by MPI_{AO2} to MPI_{PW} (r=0.767, P<0.001), and MPI_{AO2} to MPI_{PWTDI} (r=0.702, P<0.001). In CAD patients the highest correlation was found between MPI_{AO2} and MPI_{MV} (rs=0.848, P<0.001), followed by MPI_{AO2} to MPI_{PW} (rs=0.765, P<0.001), and MPI_{AO2} to MPI_{PWTDI} (rs=0.614, P<0.01).

Limitations

This study represents preliminary data from a limited number of patients. Further work is necessary to evaluate the method in larger groups of patients, as well as to assess the correlation with other established LV function indices, and to assess the prognostic significance of the method in different populations of patients.

Conclusion

Calculation of MPI based on M-mode TDI through the aortic valve could be a useful method in comprehensive echocardiographic evaluation. It could be used for current assessment of the patients and for their follow-up. Further studies in this field are necessary.

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